LMSD
1536
VOL. II
PART B
C O P (E-62)

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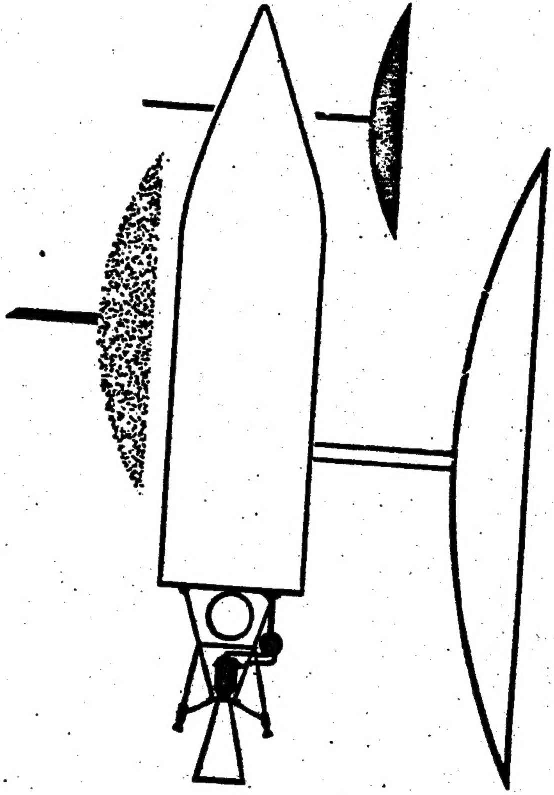

Pied Piper DEVELOPMENT PLAN

VOL. II SUB-SYSTEM PLAN

B. Propulsion

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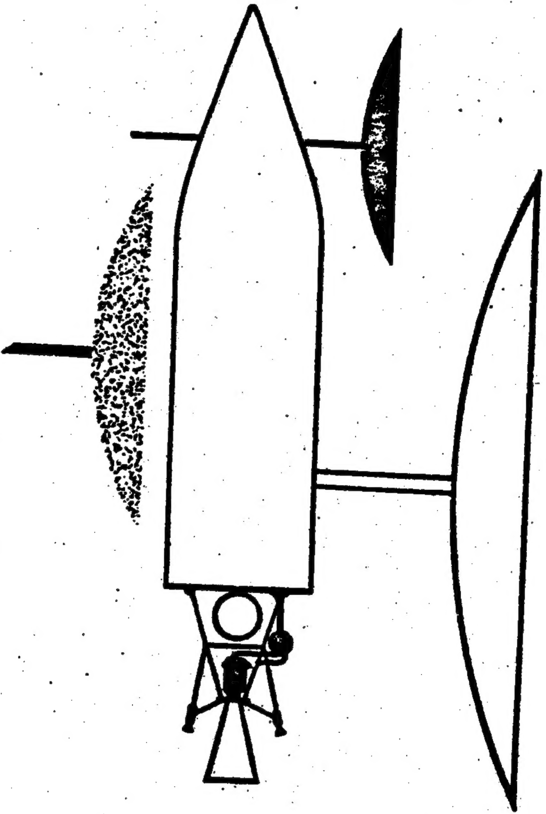

Pied Piper DEVELOPMENT PLAN

VOL. II SUB-SYSTEM PLAN

B. Propulsion

DOWNGRADED AT 12 YEAR INTERVALS;
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DOD DIR 5200.10

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FOREWORD

The Advanced Reconnaissance System (ARS) consists of a satellite vehicle containing equipment to perform visual, ferret, and infrared reconnaissance, together with the necessary system of ground stations and data processing centers.

This Development Plan for the accomplishment of the ARS was prepared by the Missile Systems Division, Lockheed Aircraft Corporation and its subcontractors, CBS Laboratories and Eastman Kodak Company. The specifications for the system were determined in the course of a one-year study now being conducted for the United States Air Force under contract AF 33(616)-3105. The plan is presented in two parts; Volume I, System Plan, and Volume II, Subsystem Plan. The subsystems are described in separate books, Volume II-A through II-L.

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Subsystem B-Propulsion

RDB PROJECT CARD (Form DD 613)

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- Milestones
- Hardware Delivery
- Test Schedules
- R and D Schedules

Tab 3 R and D Tests (Form ARDC 105)

Tab 4 R and D Test Aircraft (Form ARDC 106)

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Tab 7 R and D Contract Funds

Tab 8 Estimate of Manpower Requirements

APPENDIX

1. Pioneer Vehicle Propulsion System
2. Advanced Vehicle Propulsion System

~~SECRET~~
~~SECURITY CLASSIFICATION~~

MSD 1536
1 Mar 56

RDB PROJECT CARD

TYPE OF REPORT: New System - Development Plan

REPORTS CONTROL SYMBOL DD-RDB(A)448

1. PROJECT TITLE: PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCL.) (PIED PIPER)

2. SECURITY: ~~SECRET~~

3. PROJECT NUMBER: 3115

4. INDEX NUMBER:

5. REPORT DATE: 1 March 1956

6. BASIC FIELD OR SUBJECT:

7. SUBFIELD OR SUBJECT SUBGROUP:

7A. TECH. OBJ.

8. COGNIZANT AGENCY:

9. DIRECTING AGENCY:

OFFICE SYMBOL:

TELEPHONE NO.:

10. REQUESTING AGENCY:

11. PARTICIPATION, COORDINATION, INTEREST:

12. CONTRACTOR AND/OR LABORATORY: Lockheed Aircraft Corp
Missile Systems Division

CONTRACT/W.O. NO.: AF 33(616)-3105

13. RELATED PROJECTS:

14. DATE APPROVED:

15. PRIORITY: Maximum

16.

17. EST. COMPL. DATES

RES.

DEV.

TEST

OP. EVAL.

18. FY | FISCAL ESTS. (M $)

19.

20. REQUIREMENT AND/OR JUSTIFICATION

a. Equipment is required for propulsion and control of the satellite stage vehicle of the Advanced Reconnaissance System.

b. Propulsion units will provide the velocity increment required after booster separation and the control forces required to orient the vehicle into orbit during this acceleration.

22. RDB | SN | CN | IC & P

X. | L. | C.

DD FORM 1 JAN 52 613

B, p 1

R&D PROJECT CARD
CONTINUATION SHEET

SECRET
SECURITY CLASSIFICATION

MSD 1536
1 Mar 56

1. PROJECT TITLE
PROPULSION SUBSYSTEM
FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED)
(PIED PIPER)

2. SECURITY OF PROJECT: SECRET

3. PROJECT NUMBER: 1115

4.

5. REPORT DATE: 1 March 1956

of approximately 60 to 100 seconds. The engine assembly will have a fixed thrust mount, and will weigh approximately 135 pounds.

The engine starting system will accomplish ignition and cutoff of the sustainer and control engines on command from the Guidance and Control Subsystem. The sustainer engine is started 2 seconds after ignition of the control engines. The cutoff command from the Guidance and Control Subsystem activates the engine cutoff sequencer. Propellant to the sustainer engine is shut off, and the control engines operate alone for 2 additional seconds to correct attitude disturbances induced by sustainer engine cutoff.

2a. Pioneer Control Engines

b. Contractor: Aerojet-General or Reaction Motors, Inc.

c. Two control engines provide lateral and roll control of the vehicle. They will orient the vehicle and its thrust vector as directed by the Guidance and Control Subsystem and will position the vehicle in orbit. For the Pioneer vehicles the thrust of each engine will be approximately 150 pounds for a duration of about 60 to 100 seconds. The engine assemblies will include a gimballed thrust mount capable of deflection through ± 30 degrees in a square pattern.

3a. Pioneer Propellant Feed System

b. Contractor: Aerojet-General or Reaction Motors, Inc.

c. A gas-pressurized propellant feed system is used in the Pioneer vehicles and will consist of fuel and oxidizer tanks, a tank pressurization gas supply, valves, and plumbing. The tanks will be insulated and will operate at approximately 330 psi. Pressurization gas will be heated helium. Initial operation of control engines and starting of sustainer engine in a gravity-free field is accomplished by use of a bladder inside the tank and attached to the pressurizing gas inlet. The bladder ruptures after sufficient acceleration is attained to ensure proper orientation of the liquid in the tanks. The subsystem dry weight will be approximately 530 pounds.

4a. Pioneer Control Engine Actuator System

b. Contractor: Aerojet-General or Reaction Motors, Inc.

c. The control engine actuators will be package units consisting of an electrically driven hydraulic pump, servo-valve, actuator, and position feed-back potentiometer. Electrical power will be supplied by the auxiliary power subsystem.

R&D PROJECT CARD
CONTINUATION SHEET

SECRET
SECURITY CLASSIFICATION

MSD 1536
1 Mar 56

1. PROJECT TITLE PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) (PIED PIPER)	2. SECURITY OF PROJECT ~~SECRET~~	3. PROJECT NUMBER 1115
	4.	5. REPORT DATE 1 March 1956

21 a. Brief and Operational Characteristics

This subsystem will provide the satellite with the following: (1) thrust to attain the desired orbit; (2) lateral and roll control to effect the transition maneuver into orbit, and proper orientation of the vehicle with respect to its line of flight; (3) a propellant feed system; (4) a propellant flow and utilization control; and (5) means of effecting ignition and cutoff of the vehicle propulsion units in a safe and reliable manner.

It will be capable of starting in the absence of gravity and external pressure.

21 b. Approach

The design of this subsystem will provide sufficient margin to ensure attainment of the required orbit even with significant variations in booster performance and with substantial growth in vehicle weight and payload requirements.

Components will be selected for:

Pioneer Vehicles: These are within the current state of the art and will be available in schedules compatible with Phase I of the Advanced Reconnaissance System, and as an alternative,

Advanced Vehicles: These will provide an increase in specific impulse of at least 10 percent over presently available values and are within such state of development that reliable operation and availability within schedules compatible with that of the Advanced Reconnaissance System can be predicted.

For both phases, backup alternate developments are considered.

Major targets of the development program will be availability, compatibility with the schedules, reliability, a propellant supply system of minimum complexity and weight, and high performance (specific impulse).

21 c. Subsystem Tasks

1a. Pioneer Sustainer Engine

b. Contractor: Aerojet-General or Reaction Motors, Inc.

c. The sustainer engine will provide the required acceleration to the vehicle as the orbit is approached. The specific impulse at altitude is 278 seconds. Thrust will be approximately 7500 pounds for a duration

DD FORM 613-1 1 FEB 53 PREVIOUS EDITIONS OF THIS FORM MAY BE USED

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SECRET
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R&D PROJECT CARD
CONTINUATION SHEET

~~SECRET~~
SECURITY CLASSIFICATION

MSD 1536
1 Mar 56

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) (PIED PIPER)	~~SECRET~~	1115
	4.	5. REPORT DATE 1 March 1956

5a. Advanced Sustainer Engine with Integral Control System

b. Contractor: North American Aviation or Aerojet-General

c. For the Advanced vehicles the proposed engine is in process of contractor-sponsored development by North American Aviation, Inc. Propellants of this engine are fluorine and ammonia. In the Advanced engine, four control engines, hinged for deflection in one plane, may be used. This system may be replaced by utilizing turbo-pump exhaust in a similar manner.

6a. Advanced Propellant Utilization Control

b. Contractor: North American Aviation or Aerojet-General

c. The propellant utilization control will accomplish simultaneous exhaustion of fuel and oxidizer by a continuous comparison of tank levels. A departure from the proper ratio of levels, corresponding to the ratio of fuel to oxidizer, will be sensed. This signal is amplified and used to actuate servomotors and valves in the propellant supply lines. Thus, the control satisfies engine demand fuel-oxidizer ratio and ensures simultaneous exhaustion of both propellant tanks.

7a. Advanced Propellant Feed System

b. Contractor: North American Aviation or Aerojet-General

c. In the Advanced vehicle a conventional turbopump propellant feed system is used. An additional pressure-fed system will provide sufficient propellant for the control engines for operating 2 seconds before and 2 seconds after main engine operation in gravitational-free field. This system also provides propellant to the turbopump gas generator of the sustainer engine for starting purposes.

21 d. Other Information

1. The performance characteristics of the subsystem are predicated on specified performance of the XSM-65 as a booster unit. Allowance has been made for some degradation in booster performance and also for booster guidance and control limitations which result in less than optimum trajectory.

2. No existing equipment is available which possesses the performance characteristics required of the entire subsystem. Standardized or off-shelf items are used (valves, plumbing, etc.) whenever their characteristics are demonstrated to be of required performance and reliability.

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~~SECRET~~

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In addition to these requirements both the sustainer engine and the control engine will be capable of starting in a zero gravity field and in vacuum. The control forces must be available for two seconds prior to the sustainer engine ignition to correctly align the longitudinal axis of the orbital stage with respect to the desired trajectory, and for more than one second after sustainer engine shutdown to correct missile attitude during the thrust decay phase when sustainer engine thrust misaligments may occur. In addition, the propulsion system will be capable of withstanding the environment existing during boost (accelerations up to 10g, vibrations aerothermodynamic heating of propellants and components) and the coast period between booster stage burnout and orbital stage propulsion initiation (gravity-free conditions).

C. Solution

Because of the high degree of availability, the Project Vanguard engine being developed by the Aerojet General Corp. is proposed for the pioneer sustainer engine. It will be installed in a fixed thrust mount. Attitude control engines will be supplied. This method was selected because it corresponds to the present design approach to the operational vehicle.

As an alternative, the sustainer engine could be gimbal mounted without major modification to the present Vanguard engine design. The final selection of the type of thrust mount will be made after a further study to be conducted during the next four months.

A summary table of the operational characteristics of these propulsion systems is given in Table I.

Table I

OPERATIONAL CHARACTERISTICS OF PROPOSED PROPULSION SUBSYSTEMS

	PIONEER VEHICLE		ADVANCED VEHICLE	
	PRIMARY	ALTERNATE	PRIMARY	ALTERNATE
Contractor	Aerojet General	Reaction Motors	Rockodyne	Aerojet General
Propellant Feed System	Pressure (1)	Pump	Pump	Pump
Thrust (Vacuum)	7,500 lbs	9,600 lbs	20,000	15,000 - 20,000
Specific Impulse (Vacuum)	273 - 278	286	$326^{(4)}$ $342^{(5)}$	303
Propellant System	WFNA - UDMH	90% H_2O_2-JP-5	F_2 - NH_3	LOX - JP-4
Mixture Ratio	2.80	7.0	$2.1^{(4)}2.7^{(5)}$	2.33
Bulk Density	1.20	1.39	$1.09^{(4)}1.14^{(5)}$	1.00
Nozzle Area Ratio	20:1	30:1	15:1	25:1
Weight	163	200	375	

Notes:
1. Hot gas pressurization system
2. No film cooling
3. Including gas generator propellant
4. Initial development engines
5. Prototype and production engines

II. DESCRIPTION

A. Tasks

(1) Pioneer Sustainer Engine

The project Vanguard rocket engine now being developed by the Aerojet General Corp. will have a single thrust chamber and a fixed thrust mount. The thrust chamber will be capable of operating for a minimum of 100 seconds, be regeneratively cooled and have a nozzle area ratio of 20 to 1. The propellant combination will be white fuming nitric acid and unsymmetrical-dimethylhydrazine injected at a normal mixture ratio of 2.8. Because the propellants are hypergolic no separate ignition system will be required. However, a nozzle closure diaphram will be provided to assist in obtaining reliable starts. The engine propellant control valves are hydraulically operated by fuel pressure.

An engine which is being currently developed as a super-performance rocket engine for manned aircraft by Reaction Motors, Inc. is proposed as a back-up. This engine will be an integral unit consisting of a decomposition chamber, turbo-pump, thrust chamber, propellant control valves and necessary lines and fittings. It will use the propellant combination 90% hydrogen peroxide JP-5. The thrust chamber for use in the pioneer vehicle must be modified to have a substantially increased nozzle expansion ratio. The existing design is scheduled for flight early in 1957.

(2) Pioneer Control Engines

Two control engines having 150 pounds of thrust each will be provided. The control engine will consist of a thrust chamber, gimbal-type thrust mount, and propellant control valves and will be capable of operating for 100 seconds. The control engines will operate on propellants supplied from the main propellant feed system. Gimballing will be ± 30°.

These engines may be either liquid cooled or uncooled as determined by development testing. With a regeneratively cooled design, it may be necessary to feed propellant in excess of requirements through the cooling passages and then return this excess to the main propellant feed line.

In the event that the sustainer engine is gimballed, then the control engines may be replaced by small helium gas jets to provide roll control forces. This system will require only the development of a flow control valve.

(3) Pioneer Propellant and Feed and Starting System

The pioneer propellant feed system will be a pressure feed type propellant system. It will incorporate a helium pressurization system. Pressurization helium will be stored in a spherical tank at an initial pressure of 3,000 psi. The pressure feed system is designed to provide propellants to the engine inlets at a pressure of 300 psi.

Since the engines must be started in a gravity-free field, the ullage space in each of the propellant tanks must be remote from the tank outlet. To accomplish this, small bladders will be installed in each propellant tank at the helium inlet fittings located in the upper part of each propellant tank. These bladders will have sufficient expansion to permit the starting of the sustainer engine, provide for two seconds of control engine thrust prior to main system operation. After completion of sustainer engine starting, the bladder cells will rupture permitting a normal pressurization program to proceed. After sustainer shutdown, the control engine thrust will provide sufficient acceleration to properly orientate the remaining propellants in the tanks for the additional control engine operation.

Loading of the propellants will be accomplished with a closed cycle propellant loading system, which is described in the appendix. For accurate loading of the propellants, a propellant loading control system which will sense the correct level for the desired weight of propellant will be developed. After loading the propellant, the bladder cell will be pressurized to fill the ullage space in each tank. The pressurization system to be used with the Reaction Motors engine will be identical to the pressure feed system used with the Aerojet engine except for the tank pressure.

(4) Pioneer Actuator System

The control engine actuators will be complete package units consisting of an electric driven hydraulic pump, servo valve, actuator, and a position feed back potentiometer. Electrical power will be supplied by the auxiliary power system.

15,000 lbs. of thrust and using the propellant combination LOX-JP-4. This program will require approximately three years.

The development of a propulsion feed system for the flourine ammonia propellant system will require approximately two and one-half years of research and development. The program will consist of research in the fields of materials, especially for seals and gaskets. In addition, investigations will be made to establish the design requirements for propellant systems using flourine oxidizer.

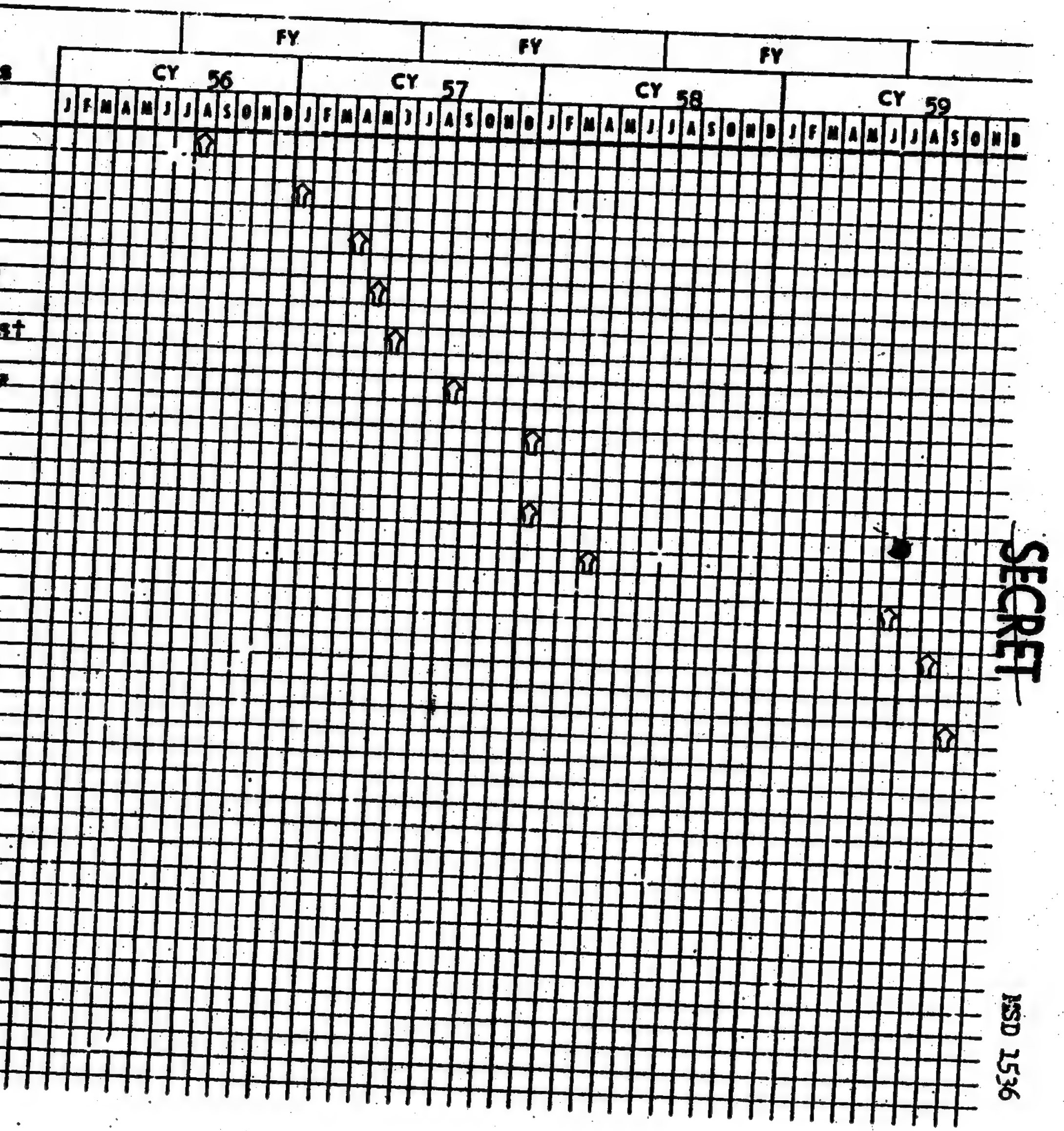
b. Flight Test Program

The propulsion system for the pioneer vehicle will be flight tested primarily on the STV. Flights 10, 11 and 12 of the STV will be used to collect propulsion system performance data, and, as required, data will be taken on subsequent flights. These data will demonstrate the suitability of the design. The early OTV's will also be instrumentated to record propulsion system performance data. To support the pioneer engine development program, flights will be made prior to STV flight #10 to investigate the ignition characteristics of the engine in a vacuum. The flight test program for the advanced engines will require extensive instrumentation to obtain performance data on turbo-pump, gas generator and thrust chamber performance. Because of the advanced engine propellant combination and the lack of background information on those propellants, this testing will be required. The advanced engine flight test program will require at least six flights on the STV.

Subsystem B - PROPULSION

Tab 2 Summary - Subsystem Milestones

Advanced Engine Spec. *
WFNA/UDMH Pioneer Engine Mock-up
STV Engine Dev. Test Complete
WFNA/UDMH Pioneer Engine Delivered
WFNA/UDMH Engine System Captive Test
STV Propulsion System Test Complete
WFNA/UDMH Pioneer Propulsion Test Complete
Advanced Engine Mock-up
WFNA/UDMH Engine NOTV Flight Test
Advanced Engine Delivery
Engine First Flight (STV)
Advanced Engine Tests (AGV)
Engine First Flight (PTV)



* F$_2$-NH$_3$ Engine proposed may be replaced by alternate LOX - JP-4 engine.

Revised Form 103

Subsystem B - PROPULSION

Tab 2 Summary - Hardware Delivery

								FY												FY												FY																	
		CY 56												CY 57												CY 58												CY 59											
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1	WFNA/UDMH Engines for STV																																																
2																																																	
3	Ground test engines																																																
4	Flight Development Engines															2	2	1	1	1	1																												
5	Flight Prototype Engines																	1	1	1																													
6																																																	
7																					1	1	1	1	1	1	1	1	1	1	1	1	1			1		1				1							1
8																																																	
9	WFNS/UDMH Engines of OTV																																																
10																																																	
11	Ground test engines																																																
12	Flight Development Engines																		2	1	2	1	2	2																									
13	Flight Prototype Engines																										2	1	1		1																		
14																																																	
15																																1	1	1		1		1	1	1	1	1	1	1	1	1	1	1
16																																																	
17	Advanced Engines for OPN*																																																
18																																																	
19	Ground test engines																																																
20	Flight Development Engines																																						2		2	1		1					
21	Flight Prototype Engines (First)																																											2		1	2	1
22																																									1	Jan 60						
23																																																	
24	T-64 Solid Propellant Rocket Engine																																																
25									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1													
26																																																	
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28																						(Continue at rate of 6/year to 1962)																											
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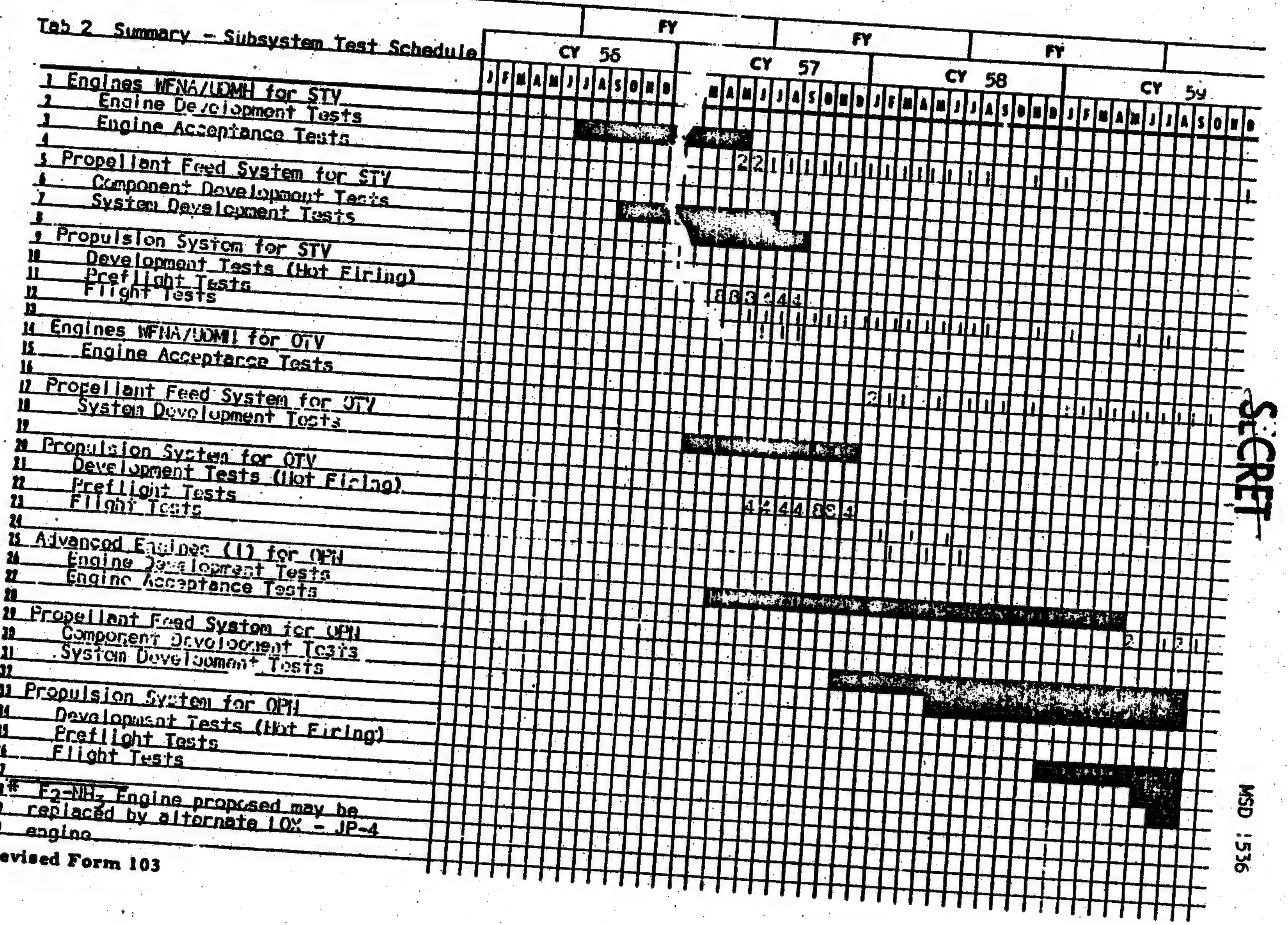
33	*F_2-NH_3 Engine proposed may be																																																
34																																																	
35	replaced by alternate LOX - JP-4																																																
36																																																	
37	engine.																																																
38																																																	
39																																																	
40																																																	

Revised Form 103

Subsystem B - PROPULSION

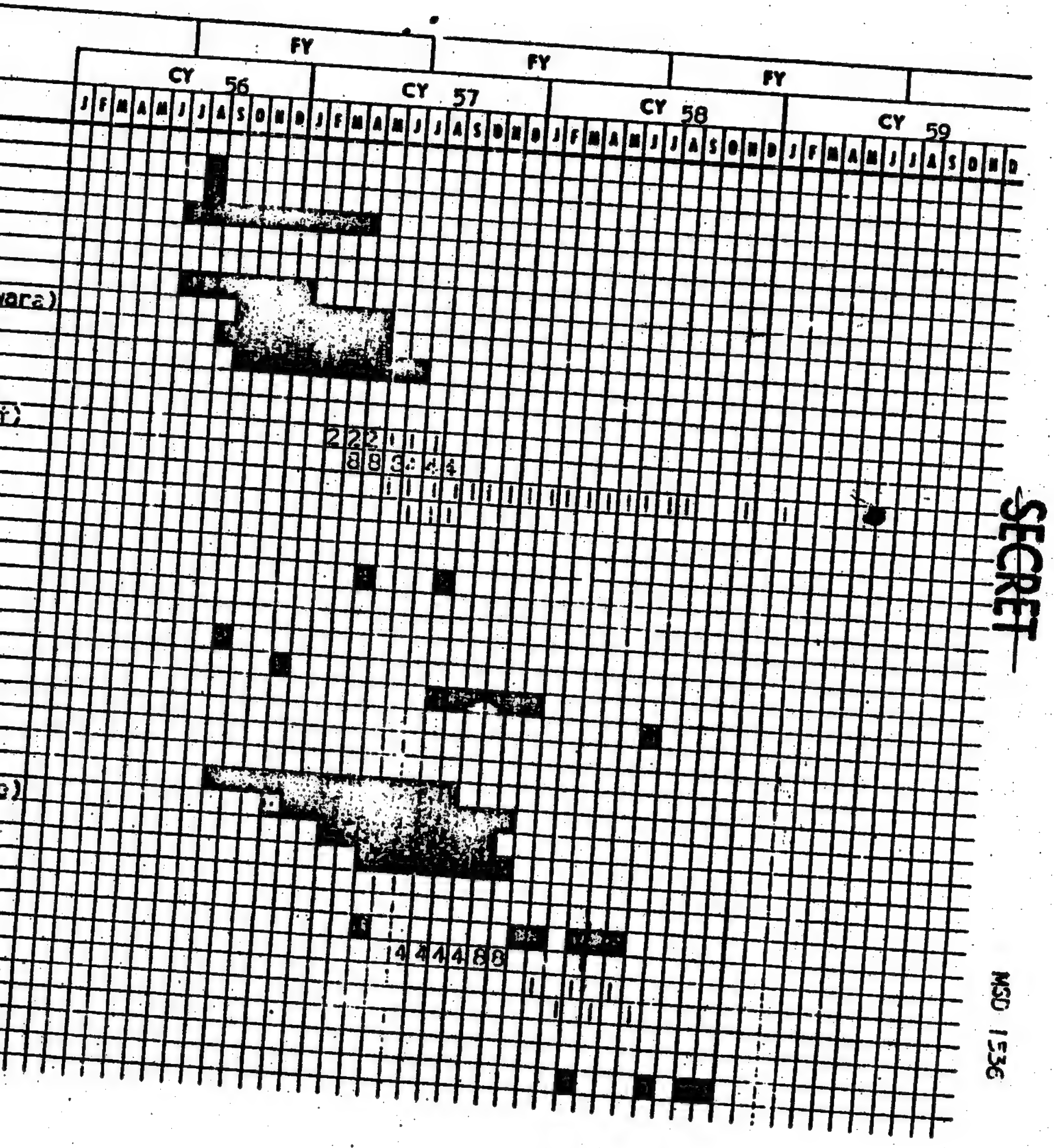
Tab 2 Summary - Subsystem Test Schedule



Subsystem B - PROPULSION

Tab 2 Summary - R & D Schedule
(Sheet 1 of 2)

1 Sustainer Engine STV WFNA/UDMH
2 Model Specification
3 Mockup
4 Experimental Engine Tests
5
6 Propellant Feed System
7 Design
8 Fabrication (Development Hardware)
9 Component Procurement
10 Development Tests
11
12 Propulsion System Development STV
13 Fabrication (Delivered for Test)
14 System Tests (Hot Runs)
15 Preflight Tests
16 Flight Tests
17
18 Operational System STV
19 Fabrication Begins
20
21 Sustainer Engine OTV WFNA/UDMH
22 Model Specification
23 Mockup
24 Experimental Engine Tests
25 Prototype Delivery Begins
26
27 Propellant Feed System
28 Design
29 Fabrication (Development Hardware)
30 Component Procurement
31 Development Tests
32
33 Propulsion System Development NOTV
34 Fabrication Begins
35 System Tests (Hot Runs)
36 Preflight Tests
37 Flight Tests
38
39 Operational System
40 Fabrication Begins



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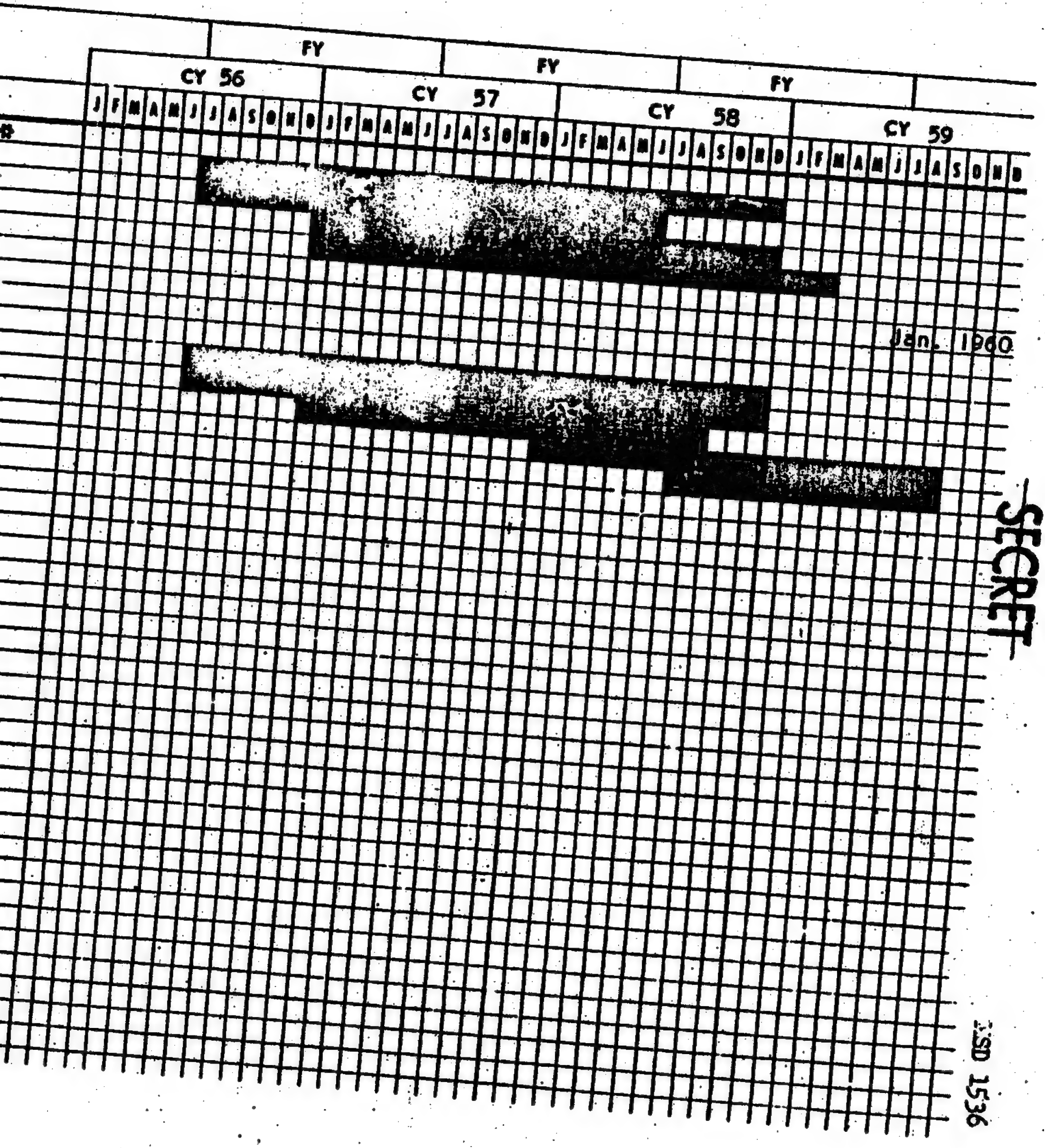
Subsystem B - PROPULSION

Tab 2 Summary - R & D Schedule (Continued)

1 Advanced Sustainer Engine - OPN *
2 Research & Support Testing
3 Component Design
4 Component Fabrication
5 Engine Design & Assembly
6 Engine Development Testing
7 First Acceptance Test
8
9 Propellant Feed System
10 Research
11 Component Design
12 Component Fabrication
13 Component Test
14 System Test



33 * F_2 - NH_3 Engine proposed may
34 be replaced by alternate LOX - JP-4
35 engine

Revised Form 103

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1\.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 3 PAGES

3. DATE

4. TITLE Subsystem B - PROPULSION

5. INITIAL ☐ CHANGE

6. NUMBER

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj)

10. CONTRACTOR

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. ROD TEST COMPL DATE
1	STV Sustainer Engine and Control Engines Assembly	Development testing of complete engine	Aerojet-General Azusa, California	Dec 1956	Apr 1957
2	STV Components (Pressurization Sys., Propellant Lines, Etc.)	Environmental testing	STF	Oct 1956	Jul 1957
3	STV Propulsion System (Engines, Press Sys. and Tanks)	System Integration and development testing	Lockheed Aircraft Corp., Systems Test Facility	Mar 1957	Sep 1956
4	STV Fropulsion System	Preflight tests	STF	(#1) May 1957	*

* As required by flight schedule - Sec. B Tab. 2

TEST CENTER APPROVAL

20. NAME	ORGANIZATION	
21. NAME	ORGANIZATION	DATE

RESPONSIBLE CENTER APPROVAL

22. NAME	ORGANIZATION	DATE

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MSD 1536

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MSD 1536

1.

R & D TEST AND TEST SUPPORT AIRCRAFT ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE | OF | PAGES

3. DATE 1 March 1956

4. TITLE Subsystem 8 - PROPULSION

5. INITIAL ☐ CHANGE

6. NUMBER

7. ITEM NUMBER	8. AIRCRAFT REQUIRED			9. ASG CODE	10. MOD REQD	11. DATE REQD AND LOCATION	12. ESTIMATED RELEASE DATE	13. RECOMMENDED DISPOSITION	14. FLT HRS EST	15. EST COST
	QTY	TYPE, MODEL AND SERIES	SERIAL NUMBER							

AIRCRAFT WILL NOT BE REQUIRED FOR TESTS OF THE PROPULSION SUBSYSTEM.

ARDC FORM 1 JUL 55 106 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

1.

R & D MATERIEL ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 2 PAGES

3. DATE 1 March 1956

4. TITLE Subsystem B - PROPULSION

5. INITIAL ☐ CHANGE

6. NUMBER

7. MATERIEL REQUIREMENTS (Indicate Items in Columnar Form using Columns as cited in Examples)

	1956	1957	1958	1959	1960	1961	1962	1963
SYSTEM TEST FACILITY								
WFNA		33.0	33.0	33.0	4.5	3.0	1.5	
UDMH		12.0	12.0	12.0	1.8	1.5	0.7	
Fluorine			0.5	50.0	70.0	65.0	95.0	31.0
Ammonia			0.5	20.0	20.0	20.0	36.0	15.0
Hydrogen Peroxide				2.1	3.0	3.0	4.0	1.5
AFMTC								
WFNA		4.5	14.0	33.0	4.0	3.0		
UDMH		1.5	5.0	12.0	1.6	1.5		
Fluorine				2.5	18.0	31.0	11.0	
Ammonia				1.0	4.5	15.0	4.5	
Hydrogen Peroxide				0.	0.8	1.5	0.5	
LOX			1050.0	506.0	685.0	685.0	343.0	
JP-4			420.0	225.0	280.0	280.0	140.0	
OPERATIONAL BASE								
WFNA			9.0					
UDMH			3.5					
Fluorine					22.0	31.0	80.0	31.0
Ammonia						15.0	26.0	15.0
Hydrogen Peroxide						1.5	3.2	1.5
LOX			685.0	675.0	1570.0	1050.0	2680.0	1050.0
JP-4			280.0	245.0	640.0	420.0	1040.0	420.0
SYSTEM TEST FACILITY								
Helium	0	10.0	30.0	30.0	40.0	35.0	40.0	15.0
N_2	10.0	30.0	30.0	30.0	10.0	10.0	10.0	10.0

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1\.

R & D MATERIEL ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 2 OF 2 PAGES

3. DATE 1 March 1956

4. TITLE Subsystem B - PROPULSION

5. INITIAL ☐ CHANGE

6. NUMBER

7. MATERIEL REQUIREMENTS (Indicate Items in Columnar Form using Columns as cited in Examples)

	1956	1957	1958	1959	1960	1961	1962	1963
AFMTC								
Helium	0	6.0	25.0	12.0	15.0	15.0	6.0	0
N_2	0	1.0	5.0	5.0	7.0	6.0	1.0	0
OPERATIONAL TEST BASE								
Helium	0	0	10.0	10.0	18.0	12.0	30.0	12.0
N_2	0	0	2.5	2.5	5.0	6.0	10.0	6.0

Note: 1. Propellant quantities in 1000 lbs.

2. Pressurizing gas quantities in 1000 standard cubic feet.

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Tab 7

R & D Contract Funds

Subsystem B - Propulsion

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Subsystem B. PROPULSION

Tab 7. R & D Contract Funds (in thousands of dollars)

	FY 57				FY 58				FY 59				FY 60	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
LAC														
(1) Research and Engineering	702	142	184	184	184	207	224	219	214	219	214	219	224	224
(a) Sub Contracts	87	87	87	87	87	175	262	437	700	875	1,137	1,312	1,575	1,750
(2) Fabrication*														
(a) Purchased Components	84	84	84	144	144	145	174	189	189	129	129	129	78	172
Sub Total	274	314	355	416	416	528	661	846	1,104	1,224	1,481	1,661	1,878	2,147
Fee	27	31	35	41	41	52	66	84	110	122	148	166	187	214
TOTAL**	302	346	392	458	458	581	787	931	1,215	1,346	1,630	1,828	2,066	2,362
Total Fiscal Year				1,498				2,697				6,019		

* Engine Installation included in Airframe costs

**Differences in totals due to rounding

Subsystem B. PROPULSION

Tab 7. (Cont.) R & D Contract Funds (in thousands of dollars)

	FY 60		FY 61				FY 62				FY 63			
[illegible]	15	16	17	18	19	20	21	22	23	24	25	26	27	Totals**
(1) Research and Engineering	187	132	162	147	149	149	74	74	65	60	60	55	35	[illegible]
(a) Sub Contracts	1,925	1,837	1,750	1,487	1,137	700	-0-	-0-	-0-	-0-	-0-	-0-	-0-	[illegible]
(3) Fabrication*														
(a) Purchased Components	168	319	351	332	344	368	212	232	208	291	390	93	-0-	[illegible]
Sub Total	2,231	2,339	2,264	1,967	1,631	1,218	286	307	273	351	451	145	35	[illegible]
Fee	228	233	226	196	163	121	28	30	27	35	45	14	3	[illegible]
Total**	2,509	2,573	2,490	2,154	1,793	1,341	316	339	301	387	496	154	39	[illegible]
Total Fiscal Year		9,510				7,790			1,343				693	[illegible]

* Engine Installation included in Airframe costs

** Differences in totals due to rounding

Tab 8

Estimate of Manpower Requirements

Subsystem B - Propulsion

Subsystem B PROPULSION

Tab 8 Estimate of Manpower Requirements

WORK ITEM	Type of Manpower	QUARTERS													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
LAC Research and Engineering	1-2-3 *														
LAC Fabrication and Assembly	4	20	28	35	35	35	40	44	43	42	43	43	44	45	45
TOTAL															

* Average:

40% Type 1 - Scientific and Technical

50% Type 2 - Engineering Support

10% Type 3 - Management and Administration

Subsystem B PROPULSION

Tab 8 Estimate of Manpower Requirements (Cont.)

WORK ITEM	Type of Manpower	QUARTERS 15	16	17	18	19	20	21	22	23	24	25	26	27		TOTAL MAN QUARTERS
LAC Research and Engineering	1-2-3 *	38	37	33	30	30	30	15	15	13	12	12	11	7		825
LAC Fabrication and Assembly	4															
TOTAL																
* Average																
40% Type 1 - Scientific and Technical																
50% Type 2 - Engineering Support																
10% Type 3 - Management and Administration																

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~~SECRET~~

Pied Piper

MSD 1536

LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION

APPENDIX

~~SECRET~~

Subsystem B - PROPULSION

APPENDIX

1. PIONEER VEHICLE PROPULSION SYSTEM

1.1 System Description

The propulsion system will consist of a pressure-fed engine assembly, propellant tanks, pressurization system, propellant lines assembly and supporting components. The propellants are white fuming nitric acid (WFNA) and unsymmetric dimethylhydrazine (UDMH). The proposed propulsion system is shown schematically on Fig. 1-1.

The proposed design will incorporate the control engines and sustainer engines as an integrated power package. Initiation of engine operation occurs after the coast phase on a signal from the vehicle guidance system. The control engines start approximately two seconds prior to the sustainer engine to orient the missile axis. For safe, reliable starts, an oxidizer lead will be used.

1.2 Engines

1.2.1 Sustainer Engine

The sustainer engine, proposed by Aerojet-General Corporation, will consist of a single thrust chamber assembly (including mount); propellant control valves; and auxiliary equipment to start, operate, and shut down. The thrust chamber is of tubular wall construction, regeneratively cooled and will be rated at 7500 pounds thrust in

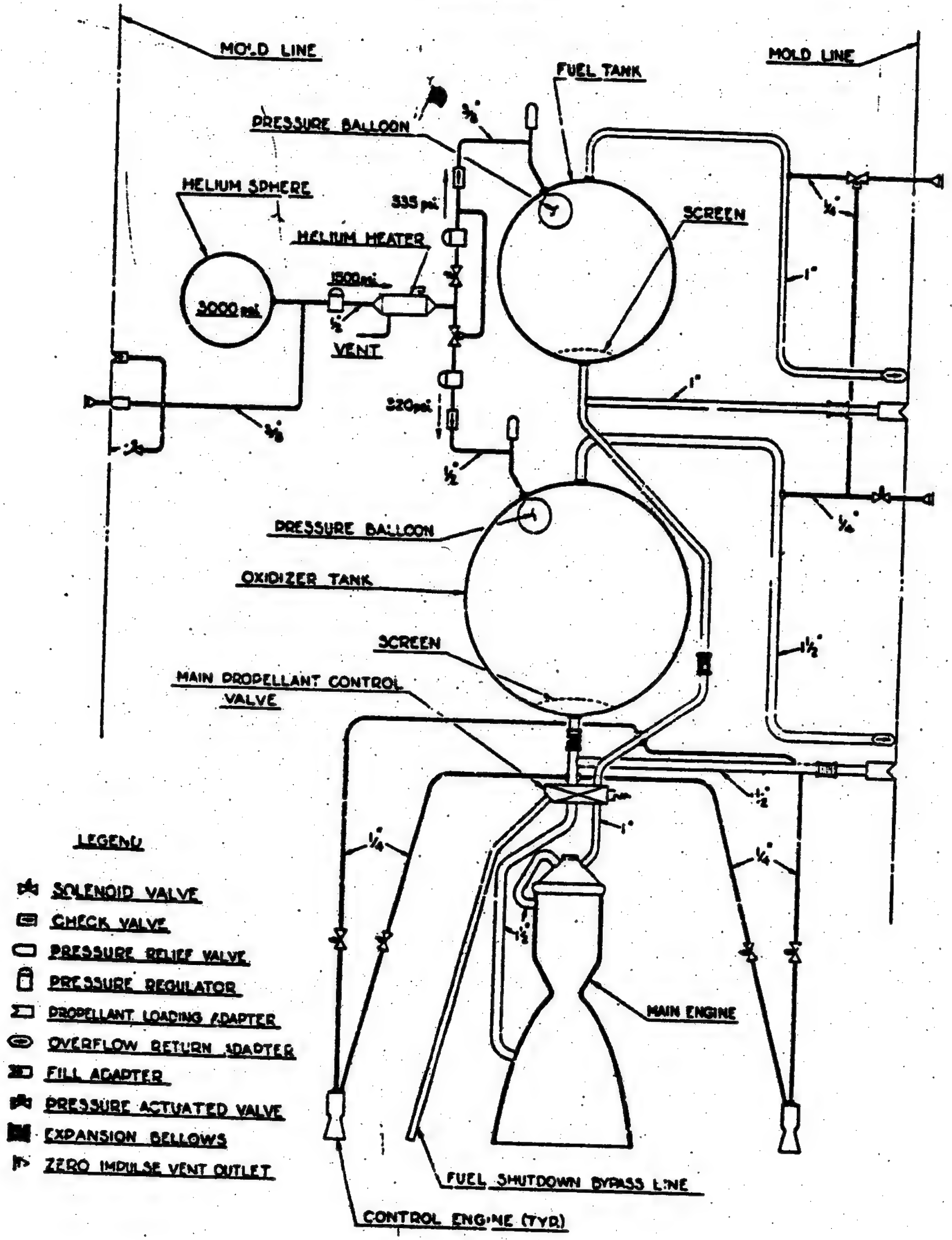

Fig. 1-1 Propulsion System

vacuum for a duration of 100 seconds at 200 psi chamber pressure. With a nozzle expansion ratio of 20:1 and a propellant mixture ratio of 2.8:1, a specific impulse of 273 to 278 seconds will be obtained. The flight version of the engine will incorporate a minimum of controls since failure aborts the flight without hazard because of the vehicle's remote location.

Performance tolerances provide for an impulse decay tolerance of ± 100 lb-sec, a starting pressure chamber surge not greater than 125 per cent of maximum rated chamber pressure and normal operating pressure oscillations not to exceed ± 5 per cent of normal operating chamber pressure. In order that adequate testing may be performed for the engine prior to flight, the life expectancy of the thrust chamber will be five tests having a duration of 120 seconds each. Early models of the thrust chamber will incorporate a stainless steel tubular wall design weighing approximately 90 pounds. If developments are successful, this will be replaced with an aluminum chamber and thereby save approximately 60 pounds. A schematic diagram of the engine assembly is shown on Fig. 1-2.

1.2.2 Control Engine

Rated at 150 pounds thrust in a vacuum, the two control engines will consist of a thrust chamber, gimbal type thrust mount, and control valves. The operating tolerances applying to the sustainer engine will, in general, apply to the control engine. No value has been fixed as yet for the impulse decay tolerance.

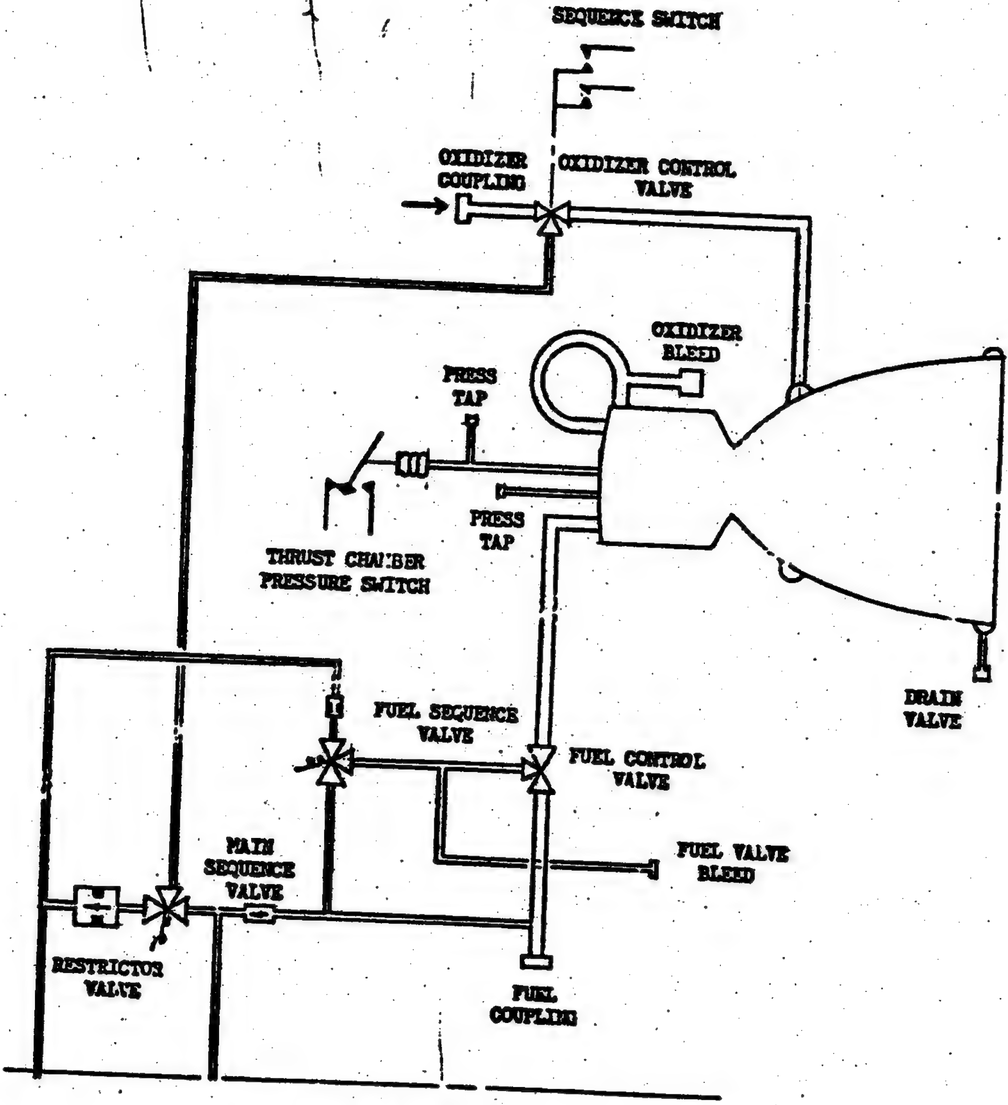

Figure 1-2 Schematic Diagram - Sustainer Engine

The control engine thrust chamber as presently conceived will be ceramic lined. Further investigation may show, however, that regenerative cooling is more feasible.

1.2.3 Engine Weight

The calculated weights of various components of the rocket engine assembly are as follows:

Thrust Chamber (Steel)	90 lb.
Thrust Chamber Mount	8
Valves and Regulator	21
Electrical Sequence Unit	7
Plumbing	7
Two Control Engines (including valves)	16
TOTAL	149 lb.

1.2.4 Pressurization System

A helium pressurization system to feed the propellants to the thrust chamber provides a pressure of 300 psi at the thrust chamber inlets. Helium will be stored in a steel sphere at a pressure of 300 psi and will be fed upon demand through a pressure regulating system and heater to the propellant tanks. The oxidizer tank will be pressurized to 320 psi and the fuel tank, to 335 psi.

Proper orientation of the required ullage space in each tank under gravity free conditions is assured by providing a bladder around the pressure gas inlet. This bladder is dimensioned to permit expansion for the expulsion of sufficient propellant for 2 seconds operation of the control engines prior to sustainer engine start and for starting the sustainer engine. After full thrust is obtained, the pressurizing gas will rupture the bladder and pressurization will continue in the usual way. Upon sustainer engine shutdown, an additional one second of control engine thrust will be required to adjust missile attitude disturbances resulting from thrust misalignments during shutdown. During this period the control engines will provide sufficient acceleration to position the propellants within the tanks.

1.2.5 Propellant Loading System

Because WFNA and UDMH give off toxic and irritating fumes, a closed-cycle type of propellant loading system is provided. The required fill and flow return adapters will be mounted at the missile mold line and will provide for rapid connection of filling nozzles and return flow adapters. The propellant tanks will be thoroughly dried and filled with either dry helium or nitrogen prior to the loading of the fuel.

1.2.6 Propellant Loading Control

Since accurate loading of propellants will increase missile performance potential, a propellant loading control system will be provided. A schematic diagram of this system is shown on Fig. 1-3. The system will consist of level sensing probes located in the missile tanks and an electronic control circuit which will be part of the missile ground supporting system. The system will be designed

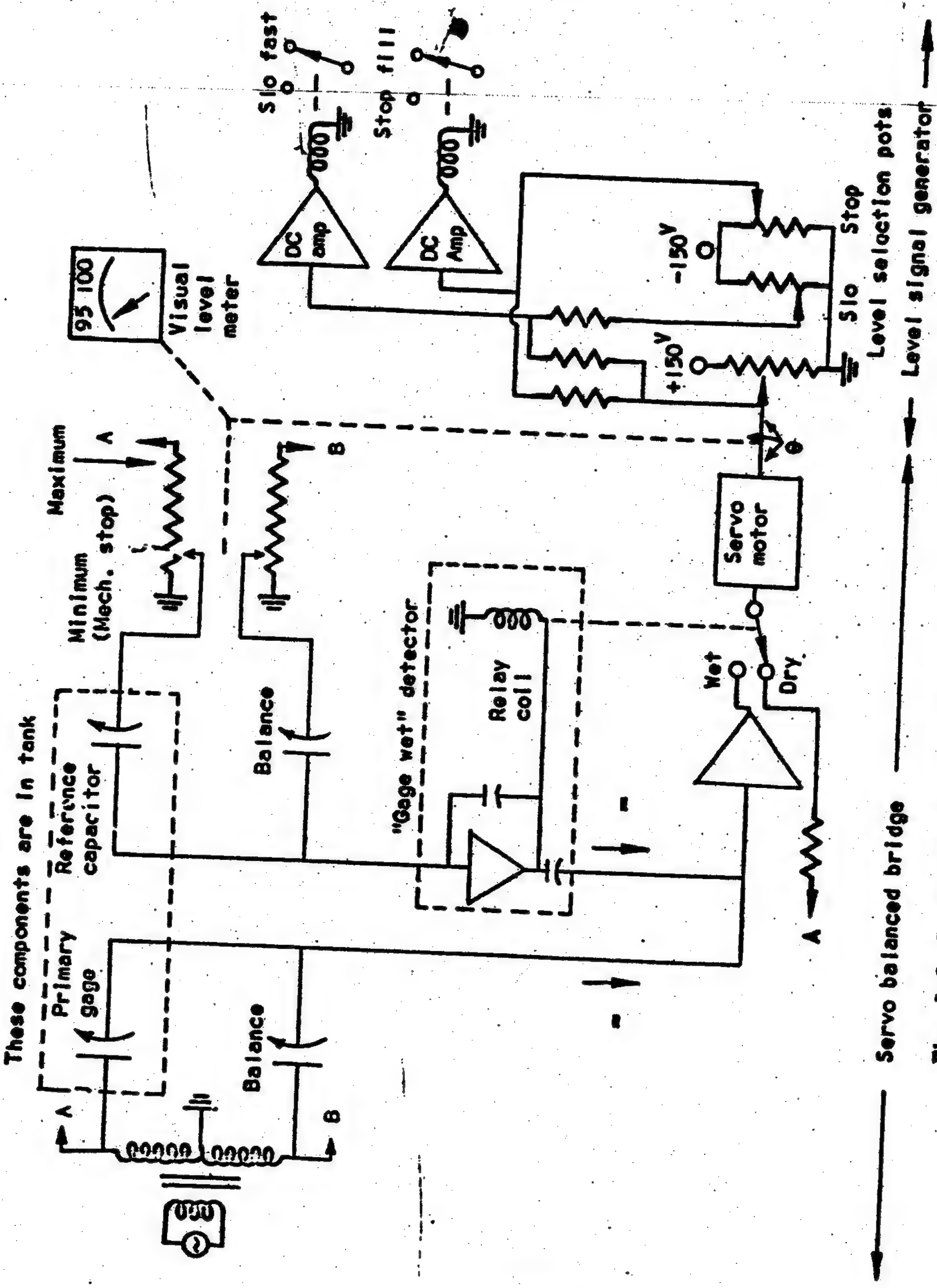

Fig. 1-3 Propellant Loading Control

so that the propellant flow to the tanks is shut off automatically when the required level is reached. Since it is proposed to load the propellant tanks at a relatively high rate of 200 gallons per minute, a vernier type of loading procedure will be used. The pumps will be slowed down after 95 per cent of the required amount is loaded. The control system on the ground will consist of a gage wet detector, servo motor, and associated amplifiers. After the proper amount of propellant has been loaded, the aforementioned bladders will be inflated in order to expel the vapor from the ullage space.

1.2.7 Tank Venting

The propellant system is so designed that tank venting may be accomplished after sustainer engine shuts down. The remaining propellants will boil-off through the vent into the vacuum outside. All overboard vents are equipped with baffles in order to avoid any impulse on the vehicle.

Careful attention was given to the question as to whether gases generated by the disassociation of nitric acid might disturb the starting process under gravity-free condition. Calculations show that the amount of gas generated can be kept small enough to ensure absorption in the liquid at pressurization, if the stay time in the tanks is limited to about one-half hour and if heat flow during the boosted exit period is reduced by tank insulation.

2. ADVANCED VEHICLE PROPULSION SYSTEM

2.1 Engine

The engine proposed by the Rocketdyne Division of North American Aviation, Inc., uses the propellant combination fluorine-ammonia. It consists of a fixed mount, turbo-pump-fed, liquid propellant engine, designed basically for the use of either fluorine and ammonia or fluorine-oxygen mixtures and hydrocarbon propellant combinations. Provisions are made for missile attitude control by directing the turbine exhaust to four hinged nozzles. To maintain attitude and roll control before and after engine shutdown (two seconds before; one second after), a bypass system around the turbine will be provided. The feasibility and basic design criteria for this engine have been established by three and one-half years of experimental investigation of fluorine oxidized rocket propellant systems. The turbine in the turbo-pump assembly is powered by the decomposition of hydrogen peroxide. The hydrogen peroxide is provided by a positive displacement pump driven by the vehicle auxiliary power system.

The four hinged nozzles provided for missile attitude control are mounted on a simple spur gear integral with the hinged section of the nozzle and driven by a gear or rack which is actuated by a hydraulic piston. Because of its simplicity and because it avoids impingement of exhaust gases on missile structure or other components the hinged mount system is felt to be better than a gimbal mount.

Maintenance of combustion chamber pressure and thrust level will be accomplished by the use of a calibrated type flow system.

2.2 Propellant Feed System

2.2.1 Special Design Features

The propellant feed system will be approximately as shown in Fig. 2-1. In addition to all the components of a standard propellant feed system, two special systems are incorporated.

For engine starting in a zero-gravity field, a positive displacement pumping system is provided. It consists of two cylinders into which sufficient propellant for starting the engines is trapped automatically during the filling operation. During the starting sequence, this propellant is expelled into the propellant lines by the action of a helium actuated piston.

To reduce structural shock due to vapor bubbles formation in the propellant line and pumps (burping), a positive displacement pump will provide a constant flow of cold propellants through the pump and propellant lines prior to start in both tanks.

2.2.2 Pressurization System

The helium pressurization system will provide pressure for structural integrity and maintenance of required NPSH at the pump inlets. The pressure will be approximately 20 psig in the oxidizer tank and approximately 30 psig in the fuel tank. Helium for this system will be stored in a spherical tank which is located in the oxidizer tank to reduce its volume (see Fig. 2-1). During operation the cold helium will be passed through a heat exchanger in the turbine exhaust duct to heat it to approximately 100 degrees F prior to entering the tanks.

2.2.3 Auxiliary Power Plant Propellant

A propellant flow diagram for the auxiliary power unit is also shown in Fig. 2-1. The system shown is based on the use of a monopropellant for APU operation. In this system propellant will be stored in a spherical vessel and forced by the expansion of a bladder to a small electrically-driven pump.

2.3 Propellant Utilization System

To obtain optimum use of propellant by avoiding trapping of propellant at the end of burning, a propellant utilization system will be installed. The system will consist of level sensing probes, a comparing circuit, and propellant servo-control valves, and is designed so that simultaneous exhaustion of propellants will occur. Through the use of the propellant loading control, the propellants will be loaded at nearly the correct mixture ratio (within plus or minus 0.2 per cent). Thus, initially the propellant utilization system will sense a zero error and will be self-compensating to ensure that zero error is indicated at the start of engine-operation. If during operation the mixture ratio shifts to either side of the design value, the comparison of propellant levels by a balanced bridge circuit will give an error signal; then the proper propellant flow control valve will operate to correct the unbalance in the tanks. A block diagram of the system is shown in Fig. 2-2.

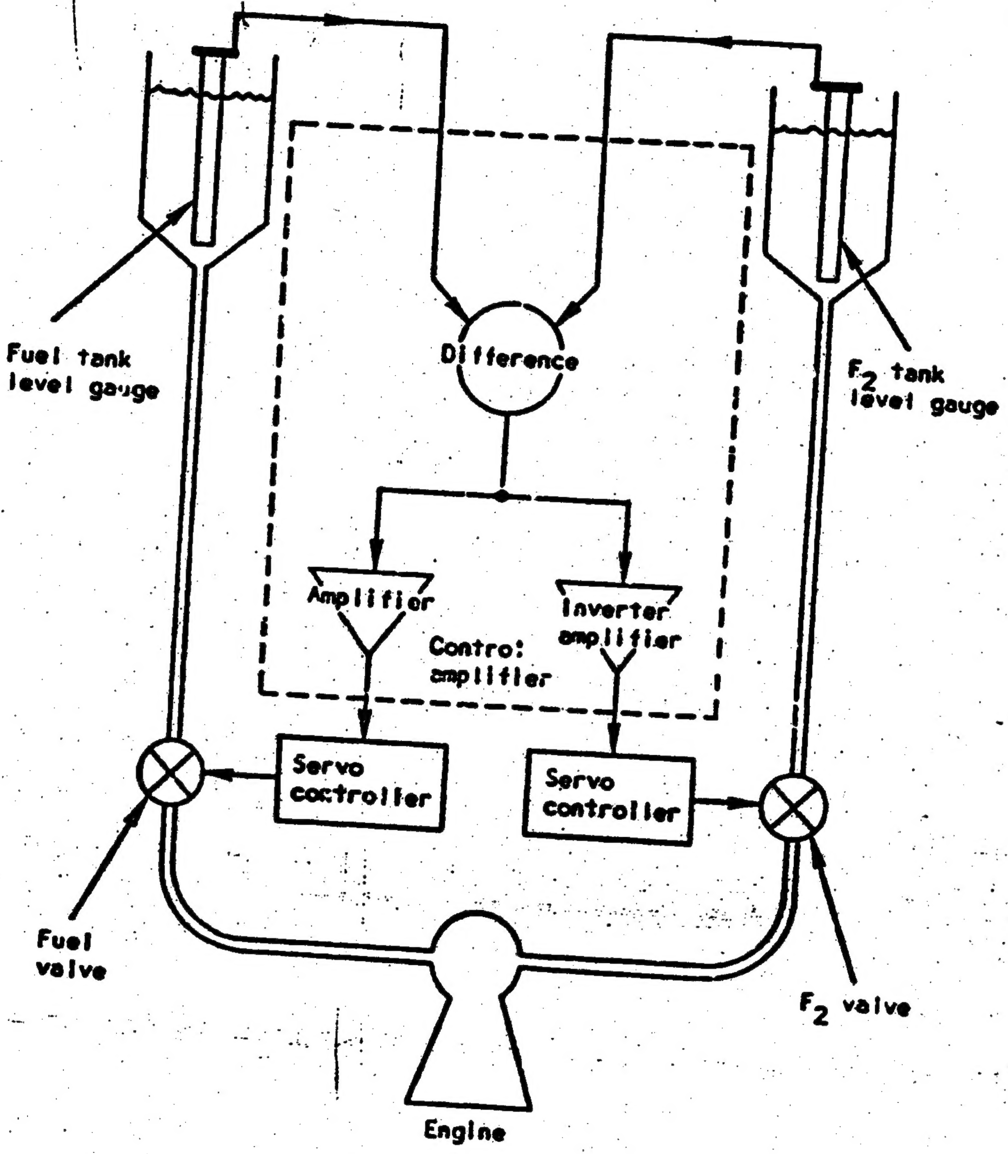

Fig. 2-2 Schematic of Propellant Utilization System

the unbalance in the tanks. A block diagram of the system is shown in Fig. 2-2.

2.4 Propellant Loading Control

A system as shown in Fig. 1-3 will be provided. This system is explained in Section 1.2.6.

END 5-66